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(54) Abstract Title
Combining lost foam and sand core casting technology

(57) A method of casting a workpiece having internal cavities uses a combination of sand core and lost foam techniques. A core of bonded granular material in the desired configuration of the voids of the workpiece is formed. The core has oppositely facing first and second surfaces with a pattern of channels extending between them. The pattern of the channels is in the desired configuration of walls for the cavities of workpiece. A first foam layer of destructible material is preformed and secured to the first surface of the core overlying one side of the channels. A second foam layer of destructible material is preformed and secured to the second surface of the core, overlying an opposite side of the channels. The assembly is placed in a refractory mold cavity, and granular refractory material is packed around the assembly. Molten metal is poured into the mold cavity into contact with the first and second foam layers, which decompose, causing the molten metal to flow into the channels, forming metal walls for the workpiece in the channels and in the spaces previously occupied by the foam layers.

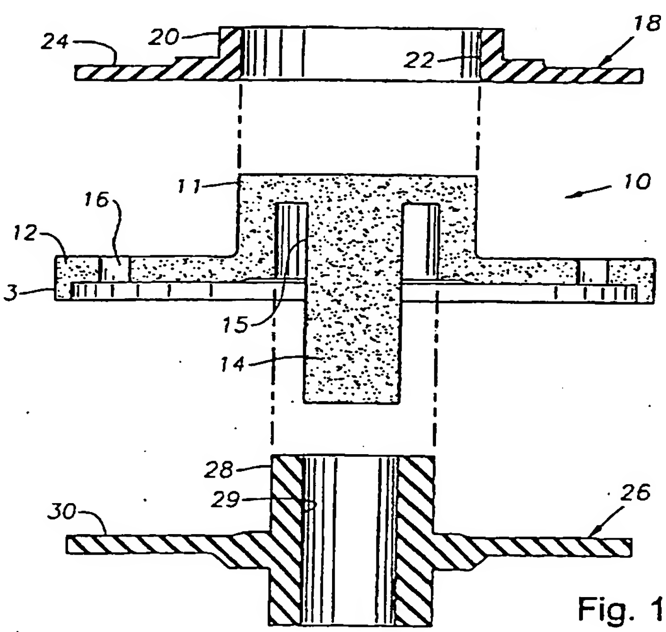

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

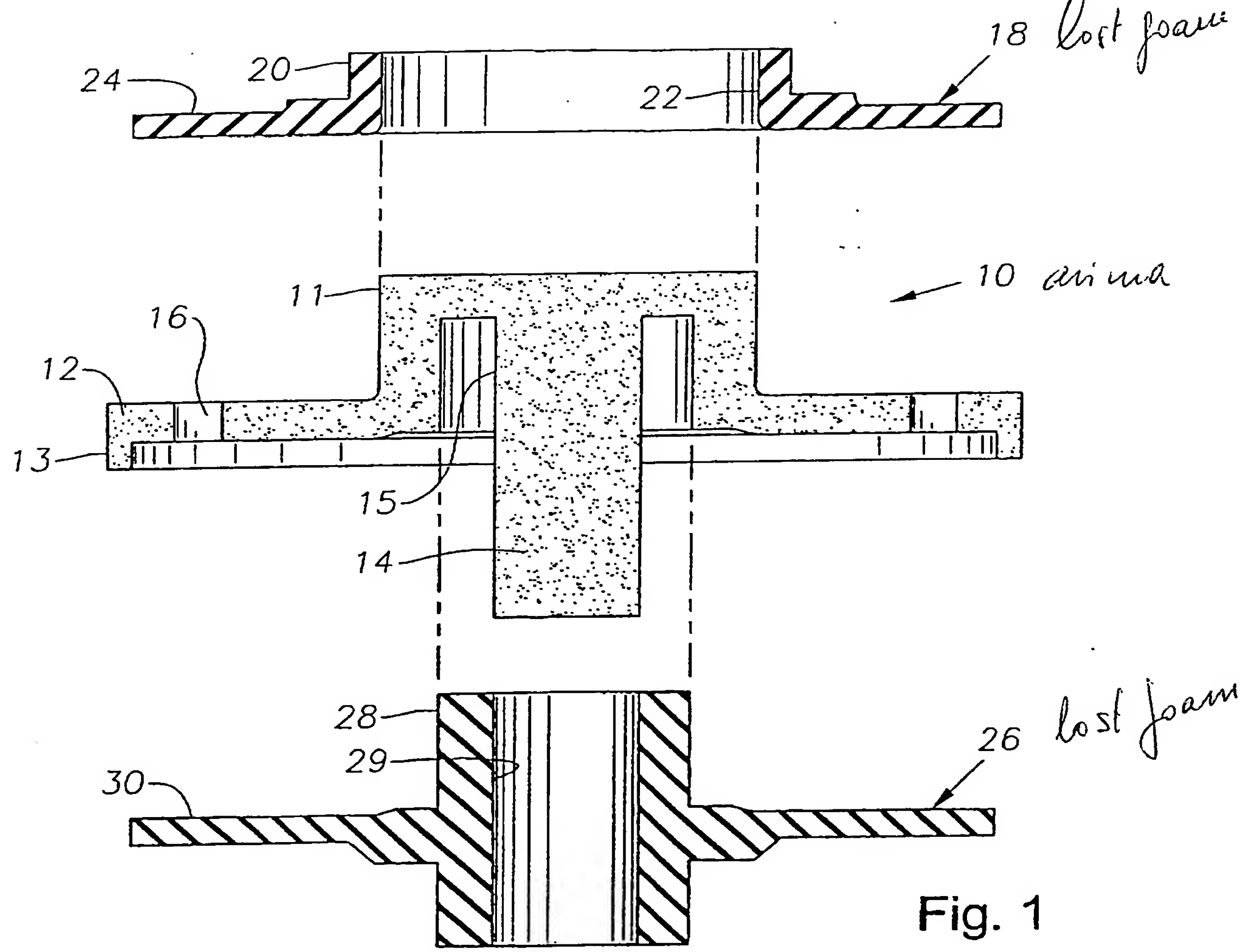
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Fig. 1

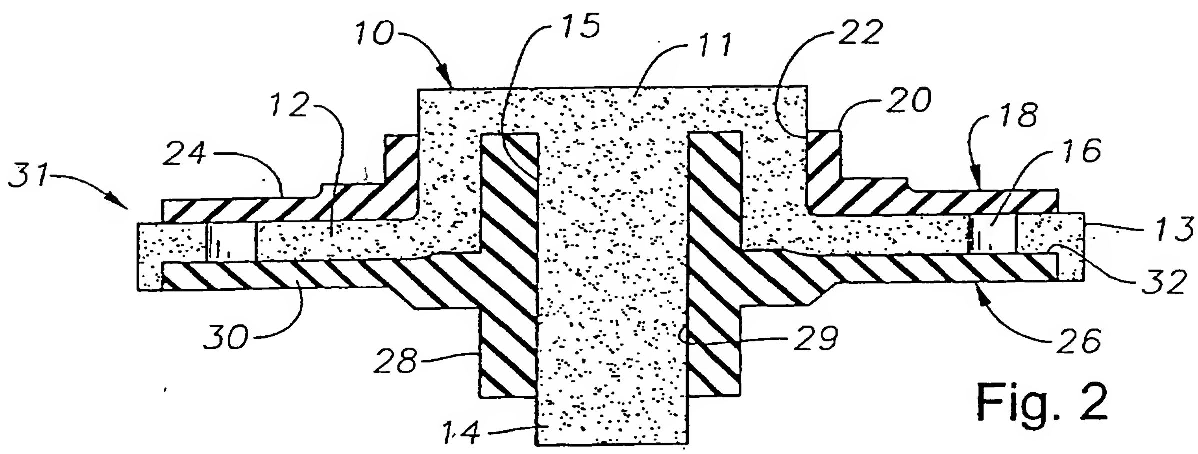
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Fig. 2

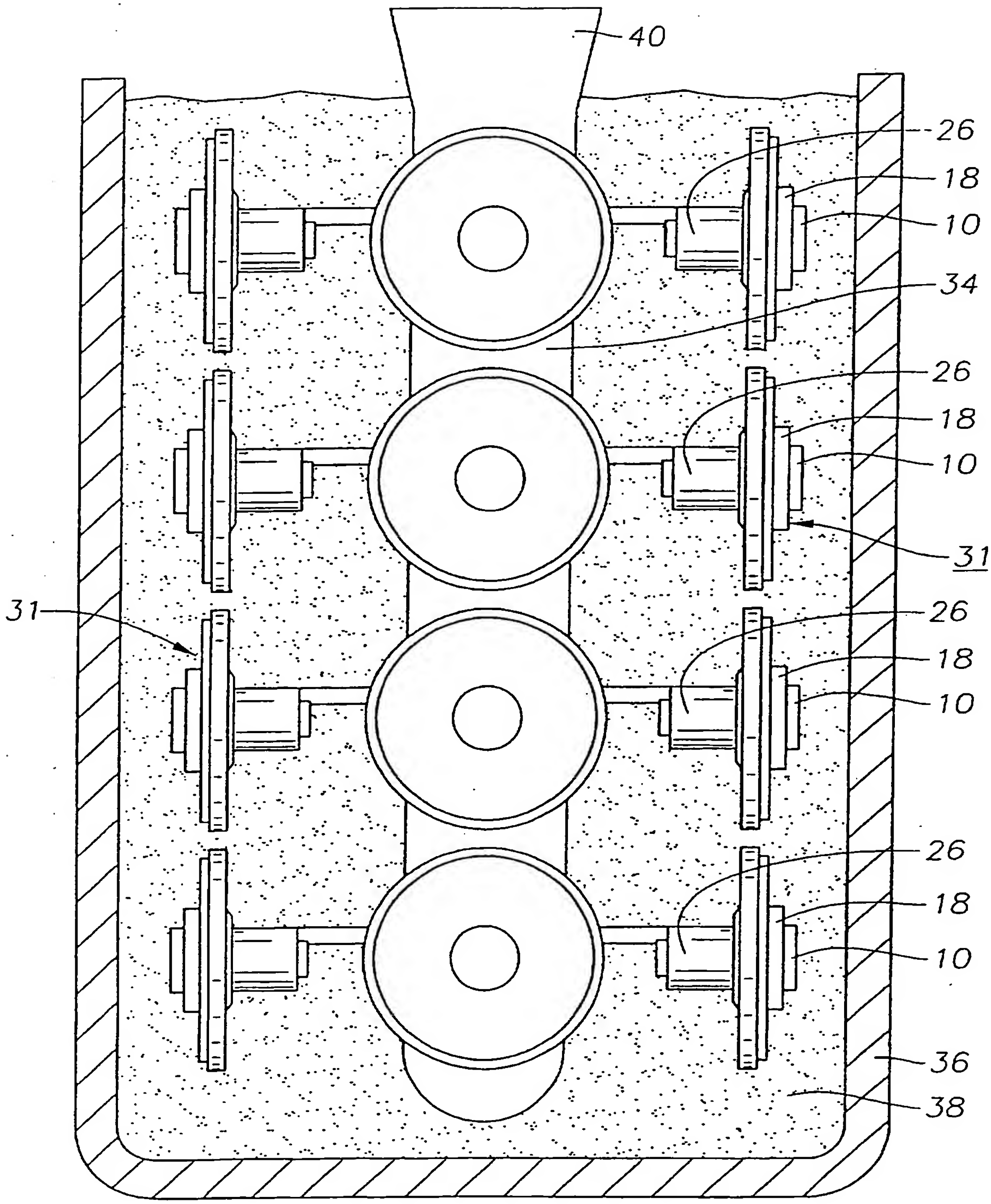

Fig. 3

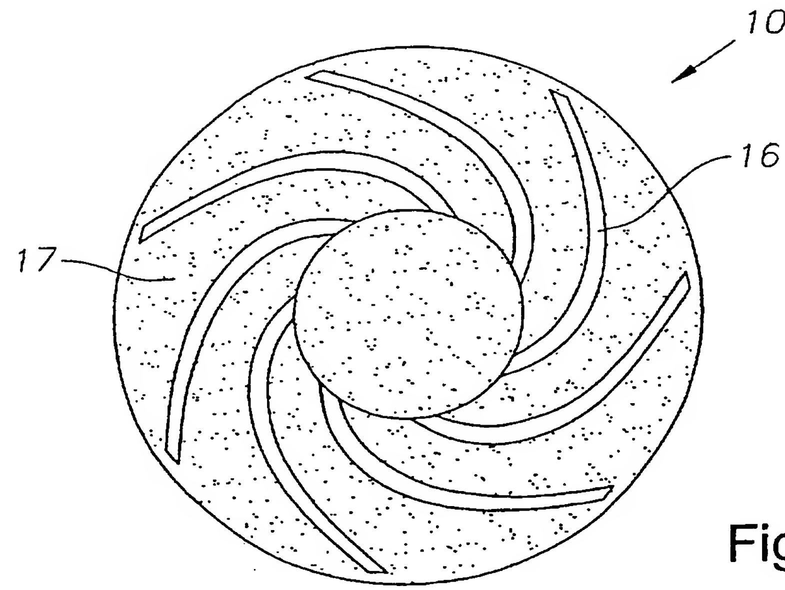

Fig. 4

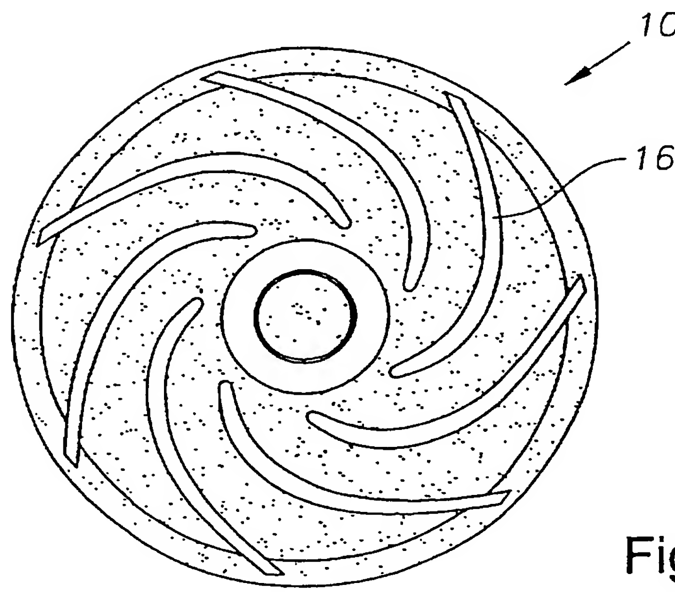

Fig. 5

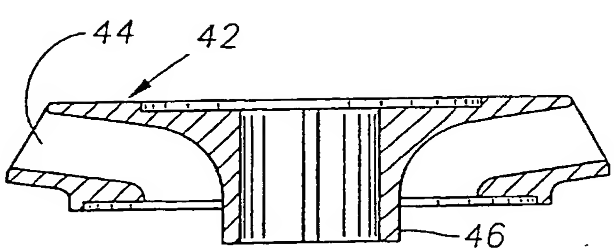

Fig. 6

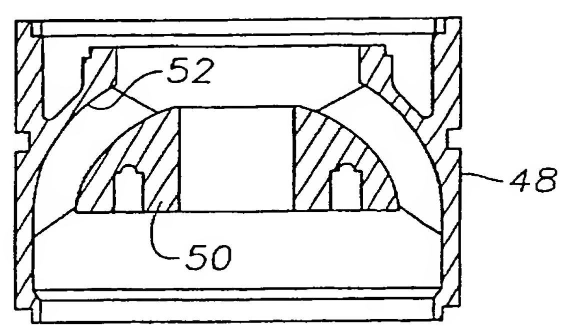

Fig. 7

LOST FOAM & SAND CORES STAGE MANUFACTURING TECHNOLOGY

The present invention relates to a foundry tooling process and method using destructible material in casting operations for producing complex internal shapes requiring a high degree of surface finish. More particularly, the invention relates to a process for producing impellers and diffusers for centrifugal submersible pumps.

Many cast parts require the formation of voids therein. An example of such castings includes impellers of pump stages in centrifugal submersible pumps.

One method for forming such castings is the lost foam method. In the lost foam method, consumable patterns, such as polystyrene foam plastic, are coated with a permeable refractory wash and then embedded in foundry sand to be replaced by molten metal. The molten metal vaporizes the foam-type pattern and a metal duplicate of the pattern is the result. The lost foam method is advantageous because it allows for net shape capacity, i.e., the ability to produce a finished or near-finished casting that requires little or no machining. However, the lost foam method is unsuitable for the geometric particularities of the hydraulic passages required in complex castings, such as impellers and diffusers. The lost foam process is not suitable to form some complex castings because of process shortcomings including limitations in thickness of the walls as well as major costs associated

with tooling, low consistency in the molding stage, low surface finish and low compression strength. Additionally, particular types of geometries result in warping of the castings. Therefore, such castings do not achieve a near net shape.

Another method for forming castings is sand molding. Sand molding uses high strength chemically bonded sand. Sand molding is not a preferred choice to form net shape parts because of mold wall movement. Additionally, some specific requirements of sand molding may only be met by high quality foundries.

Therefore, it is desirable to develop a method that results in near net shape, that is low in cost, and that avoids the shortcomings of the lost foam process. One solution is proposed in U.S. Pat. No. 4,691,754, which teaches molding a destructible layer around a first core by placing the first core into a molding machine. Partially pre-expanded polystyrene pellets are applied to the core and fully expanded, via a steam expansion step. However, a drawback with this method is that the core is exposed to moisture during the steam expansion step. It is desirable to avoid exposing the core, which is typically hygroscopic, to moisture. If the core is exposed to moisture, molten metal will come in contact with the moisture absorbed by the core when the molten metal is poured into the core. The exposure of molten metal to moisture is undesirable.

A casting method that combines a lost foam method and a sand molding method provides desired benefits without undesirable effects. The present invention is a lost foam and sand core casting method that includes the step of forming a core of bonded granular material, preferably sand or ceramic, containing voids. The core has voids formed in it that have at least two exposed sides. A first layer of lost foam destructible material is then preformed in a separate mold, preferably by an injection process. Similarly, a second layer of lost foam destructible material is preformed.

The first foam layer is positioned on one side of the core, and the second foam layer is positioned on another side of the core. The layers are glued to the core, closing off the exposed sides of the voids formed in the core.

The assembly is attached to a down sprue and lowered in a mold cavity, which is then packed with a mold media that is preferably the same as the media of the core. The assembly is vibration compacted and/or vacuum compacted within the ceramic and/or sand media. The foam layers prevent entry of mold media into the voids. Molten metal is then delivered to the mold cavity to form the casting. The lost foam layers are gasified and replaced by the molten metal as it enters the mold. The voids in the core as well as the spaces previously occupied by the foam layers are filled with the advancing molten metal. After cooling, the cast component is removed

from the mold cavity, and the material of the core, which is no longer bonded, is removed from the component.

Various embodiments of the present invention will now be described, by way of example only, and with reference to the accompanying drawings in which:

Figure 1 is a cross-sectional, exploded and simplified elevation view of a core, an upper lost foam mold, and a lower lost foam layer constructed in accordance with this invention.

Figure 2 is a cross-sectional and simplified elevation view of an assembly comprised of the core, upper lost foam layer, and lower lost foam layer of Figure 1.

Figure 3 is a side view of a plurality of the assemblies of Figure 2 lowered into a molding flask on a down sprue.

Figure 4 is a top view of the core shown in Figures 1 and 2.

Figure 5 is a bottom view of the core shown in Figures 1 and 2.

Figure 6 is a cross-sectional view of a finished pump impeller formed from the assembly of Figure 2.

Figure 7 is a cross-sectional view of a finished diffuser formed from a method in accordance with a preferred embodiment of the invention.

Referring now to Figures 1 and 2, core 10 is formed of a bonded granular material, preferably chemically bonded mullite. Mullite is a type of fine grade ceramic material. However, sand or other materials may be used, including silica

sand and a binder such as phenolic base and/or modified phenolic base resin. Core 10 may be formed by a variety of conventional techniques. The material of the first core 10 should be compacted sufficiently to act as a backing that will generate enough mold strength in conjuncture with the mullite media to create a hydraulically sound part with a near net shape configuration.

Core 10 is shaped for forming cavities in a centrifugal pump impeller, and is shown in a simplified manner in Figure 1, rather than with curved contours that would exist in practice. Core 10 is in a circular disk-shaped configuration with a central axis, an upward extending central cylindrical hub portion 11 and a radially extending flange 12. The terms upper or upward and lower or downward are used for convenience herein and not in a limiting manner. A depending lip 13 extends around the circumference of flange 12. A solid downward extending mandrel 14 extends from the lower side of core 10. An annular recess 15 with a closed upper surface is formed in the lower side of core 10, encircling mandrel 14. Flange 12 is formed with a plurality of voids or spaces 16 as shown in Figure 4. Voids 16 extend from upper hub 11 outward in a spiral or helical pattern. Each void 16 extends completely through flange 12, and has an outer end that is closed by lip 13, which extends in a continuous uninterrupted circle around flange 12. Consequently, voids 16 have exposed upper and lower sides. Voids 16 are fairly thin in width and

define fingers 17 in core 10 between them that are wider considerably than voids 16.

A protective core wash may be used to coat the surface of core 10 to enhance the surface finish of the casting. The particular core wash is customized for use with a particular alloy to minimize interaction and to meet specific permeability requirements as is known in the art.

An upper lost foam layer 18 is preformed of a cellular plastic foam material of a type that will vaporize when contacted by hot metal. The destructible material of upper lost foam layer 18 may be any type of suitable low temperature fusible substance, including a thermoplastic resinous material or any other cellular plastic material that gasifies substantially without residue. Materials that may be used include polystyrene and resinous polymerized derivatives of methacrylic acid. Various types of cellular plastic materials suitable for use in casting operations are taught in the following U.S. patents: U.S. Pat. No. 3,374,827, issued to Schlebler on Mar. 26, 1968, and U.S. Pat. No. 3,496,989, issued to Paoli on Feb. 24, 1970. The expression "destructible" as applied to the cellular plastic layer is intended to refer to materials that are quickly destroyed by molten metal. The destructible nature of the materials enables the molten metal to occupy the space originally occupied by the destructible material. In contrast, the "core" material is "non-destructible" in the sense that the

core material is able to resist the effects of the molten metal. Therefore, the core material produces a cavity in the casting.

Upper lost foam layer 18 has a radially extending flat flange 24 and a central upward extending hub 20. Unlike flange 12 of core 10, there are no voids in flange 24, rather it is solid and has flat, smooth upper and lower surfaces. An opening 22 extends through hub 20 and is sized for close reception over upper hub portion 11 of core 10. The height of hub 20 of upper lost foam layer 18 is less than the height of upper hub 11 in the embodiment shown.

A lower lost foam layer 26 of the same material as upper lost foam layer 18 is also preformed. Lower lost foam layer 26 has a central hub 28 with a passage 29 extending through it. A flat circular flange 30 extends radially outward from hub 28 at a point between the upper and lower ends of hub 28. Flange 30 is also solid with substantially flat upper and lower surfaces. Hub 28 is sized to fit closely in recess 15. Mandrel 14 of core 10 fits closely within passage 29 and protrudes slightly below the lower end of hub 28.

Upper and lower foam layers 18, 26 may be preformed in a variety of manners. Preferably, they are formed by injection molding techniques in an aluminum mold. Beads of cellular plastic material are injected into cavities in the aluminum mold, then expanded by the application of steam.

In practice, the preformed upper lost foam layer 18 is affixed to the upper side of the core 10, preferably by an adhesive, as shown in Figure 2. The preformed lower lost foam layer 26 is positioned and affixed to the lower side of core 10 by adhesive, as shown in Figure 2. The periphery of flange 30 locates within lip 13, and hub 28 extends into core recess 15. Once assembled as in Figure 2, flange 24 of upper foam layer 18 will close the upper sides of voids 16 (Figures 4,5), and flange 30 of lower foam layer 26 will close the lower sides of voids 16. Core lip 13 encloses the outer ends of voids 16. Voids 16 are thus completely sealed.

The assembly 31 of core 10, and foam layers 18 and 26 are attached to a down sprue 34 (Figure 3) and lowered into a flask 36. Figure 3 shows eight of the assemblies 31 mounted to down sprue 34 and being simultaneously positioned in flask 36. A refractory molding media 38 is packed around assemblies 31. Molding media 38 is preferably the same as the material of core 10, such as ceramic mullite. The molding media 38 is unbonded and either vacuum and/or vibration compacted in place. The media 38 closely contacts and forms to the configuration of the assemblies 31.

Molten metal is then delivered to the assemblies 31 through a sprue cup 40 and down sprues 34 to form a casting of a workpiece or component, such as an impeller or diffuser. The upper lost foam layer 18 and lower lost foam layer 26 are gasified and replaced by the molten metal as it enters the

mold. Voids 16 in core 10 (Figures 4 and 5) are also filled with the advancing molten metal. After cooling, the component is removed, and the granular media of core 10 is shaken from or otherwise removed from the component. This leaves a plurality of passages in the component where fingers 17 (Figures 4, 5) previously existed. Voids 16 resulted in lateral sidewalls being formed for the passages of the component, while foam layers 18, 26 resulted in upper and lower walls of the passages of the component.

An assembly similar to assembly 31, but more contoured, will form an impeller 42, shown in Figure 6. Impeller 46 has helical passages 44 formed therein by fingers 17 (Figures 4, 5) of core 10 and upper and lower layers 18, 26. Impeller 42 has a hub 46 formed by corresponding portions of assembly 31.

An assembly (not shown) formed in the same manner, with a core of bonded granular material and upper and lower lost foam layers will also form a diffuser 48, shown in Figure 7. Diffuser 48 has a central portion 50 and a plurality of passages 52 formed therein. Impeller 42 and diffuser 48 form a pump stage of a centrifugal pump.

The method of the invention has several advantages. By preforming the destructible material layers, then gluing the destructible material layers to a core, moisture from the steam expansion step never contacts the bonded granular material core. Additionally, the interior of the resulting casting is smooth-surfaced, free of pits and fins.

An important advantage is the use of voids in the core that are initially sealed by the foam layers, then filled with metal as the metal is introduced into the mold. The method of the invention requires no gluing lines that might occur when gluing two sand cores together. The absence of gluing lines results in an improved surface finish and dimensional stability. A casting with a complex internal geometry having a high level of surface finish may be formed. The result is a casting of complex internal geometry with a very high level of surface finish as cast, which yields improved hydraulic performance.

While the invention has been shown in only one of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the invention.

Claims

1. A method of casting a workpiece having a plurality of cavities, comprising the steps of:

(a) forming a core of bonded refractory material in the desired configuration of the cavities of the workpiece, the core having a plurality of voids formed therein which have at least one exposed side;

(b) preforming a layer of fusible material and positioning the layer over the exposed side of the voids, forming an assembly;

(c) placing the assembly in a refractory mold cavity and packing refractory media around the assembly, with the layer blocking entry of the refractory media into the voids;

(d) delivering molten metal into the mold cavity into contact with the layer, which decomposes, causing the molten metal to flow into the voids, forming interior walls of the workpiece in the voids; then

(e) removing the workpiece and the core from the mold cavity and removing the bonded refractory material of the core from the workpiece.

2. The method according to claim 1, wherein the layer is secured adhesively to the core in step (b).

3. The method according to claim 1 or 2, wherein:

step (a) further comprises forming a recess in the core;

and step (b) further comprises preforming a protrusion on the layer of a shape that matches the recess and inserting the protrusion into the recess.

4. The method according to claim 1, 2 or 3, wherein:

step (a) further comprises preforming a mandrel on the core; and

step (b) further comprises preforming a hole in the layer and inserting the mandrel into the hole.

5. A method of casting a workpiece having a plurality of a plurality of cavities therein, comprising the steps of:

(a) forming a core of bonded granular refractory material in the desired configuration of the cavities of the workpiece, the core having oppositely facing first and second surfaces with a plurality of voids extending between the first and second surfaces, the voids having exposed sides at the first and second surfaces and being in the desired configuration of interior walls for the workpiece;

(b) preforming a first foam layer of fusible material and positioning the first foam layer on the first surface of the core overlying and closing off one of the exposed sides of the voids;

(c) preforming a second foam layer of fusible material and positioning the second foam layer on the second surface of the core overlying and closing off an opposite one of the exposed sides of the voids, forming an assembly of the first and second foam layers with the core;

(d) placing the assembly in a refractory mold cavity and packing granular refractory media around the assembly;

(e) delivering molten metal into the mold cavity into contact with the first and second foam layers, which decompose, causing the molten metal to flow into the voids, forming interior walls for the workpiece in the voids; then

(f) removing the workpiece and the core from the mold cavity and removing the bonded granular refractory material of the core from the workpiece, providing the desired cavities for the workpiece.

6. The method according to claim 5, wherein in step (c), the foam layers are adhesively secured to the core.

7. The method according to claim 5 or 6, wherein in step (d) the molten metal flowing into the voids forms side walls of the cavities of the workpiece, and the molten metal flowing into the spaces occupied by the first and second layers forms upper and lower walls of the cavities of the workpiece, the upper and lower walls being joined to each other by the side walls.

8. The method according to claim 5, 6 or 7 wherein:

step (a) further comprises forming a recess in the second surface;

and step (c) further comprises preforming a protrusion on the second foam layer of a shape that matches the recess and inserting the protrusion into the recess.

9. The method according to any of claims 5-8, wherein:

step (a) further comprises preforming a mandrel on the second surface of the core; and

step (c) further comprises preforming a hole in the second foam layer and inserting the mandrel into the hole.

10. A method of casting a centrifugal pump stage component having a plurality of a plurality of passages extending outward from a central axis, each of the passages being defined by interior sidewalls and oppositely facing first and second walls, the method comprising the steps of:

(a) forming a core of bonded granular material, having outward extending fingers separated by voids, the fingers being in the configuration of the passages of the component, and the voids being in the configuration of the sidewalls of the component, the voids having first and second exposed

sides;

(b) preforming a first foam layer of fusible material and positioning the first foam layer on a first surface of the core in contact with the fingers, overlying and closing off the first exposed sides of the voids, the first foam layer having portions in the configuration of the first walls of the passages of the component;

(c) preforming a second foam layer of fusible material and positioning the second foam layer on a second surface of the core in contact with the fingers, overlying and closing off the second exposed sides of the voids, the second foam layer having portions in the configuration of the second walls of the passages of the component, the foam layers and the core forming an assembly;

(d) placing the assembly in a refractory mold cavity and packing granular refractory material around the assembly;

(e) delivering molten metal into the mold cavity into contact with the first and second foam layers, which decompose, causing the molten metal to flow into the voids, forming the interior sidewalls for the passages of the component in the voids and forming the first and second walls for the passages in the spaces previously occupied by the foam layers; then

(f) removing the component and the core from the mold cavity and removing the bonded granular material of the core from the component, providing the desired passages for the component.

11. The method according to claim 10, wherein in step (c), the foam layers are adhesively secured to the core.

12. The method according to claim 10 or 11, wherein in step (d) the molten metal flowing into the voids and spaces joins the sidewalls of the passages with the first and second walls of the passages.

13. The method according to claim 10, 11 or 12, wherein:

step (a) further comprises forming a recess in the core;

and step (c) further comprises preforming a protrusion on the second foam layer of a shape that matches the recess and inserting the protrusion into the recess.

14. The method according to any of claims 10-13, wherein:

step (a) further comprises preforming a mandrel on the core; and

step (c) further comprises preforming a hole in the second foam layer and inserting the mandrel into the hole.

15. The method according to any of claims 10-14, wherein in step (a), the fingers of the core are formed to extend outward in a spiral pattern.

16. The method according to any of claims 10-14, wherein in step (a), the fingers and the openings of the core are formed to extend outward in a spiral pattern, and wherein the core is formed with an annular lip surrounding outward ends of the voids and joining outward ends of the fingers.

17. A method of casting an impeller and/or diffuser, comprising the steps of:

forming a core of bonded refractory material containing voids;

preforming at least one destructible material layer;

gluing said at least one destructible material layer to said core to seal said voids and prevent moisture from

contacting said core;

placing said core and said at least one destructible material layer into a mold; and

introducing molten metal into said mold.

18. A method of casting an impeller and/or diffuser substantially as hereinbefore described with reference to the accompanying drawings.